Electrical Measurements

Code: EPM1202

Lecture: 4 Tutorial: 2 Total: 6

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Multimeter “AVO meter”

It is used for multi-purpose measurements

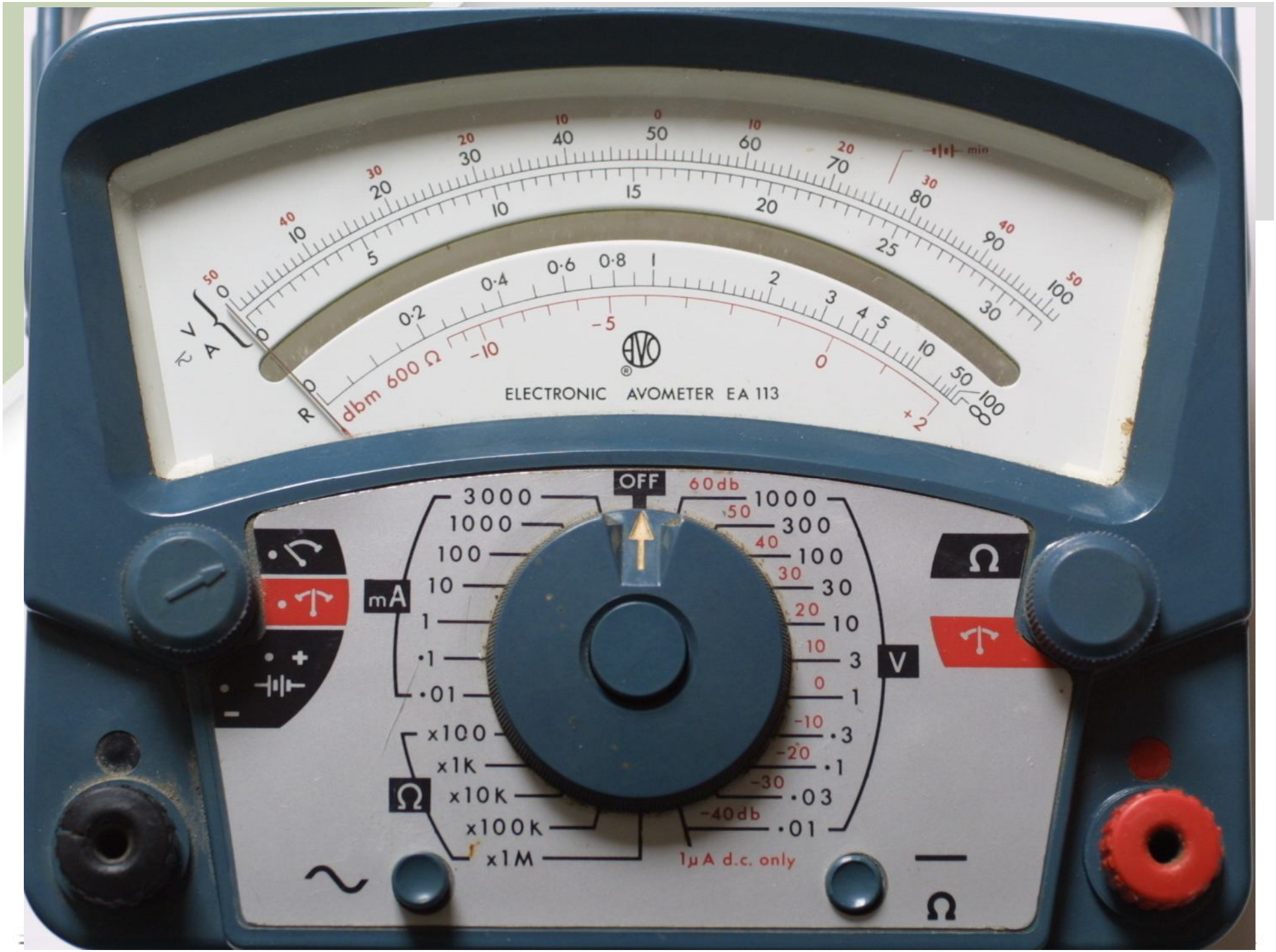
AVO stands for Amperes, Volts and Resistance

A switch is used to select the required variable

The switch enables also selecting different scales

Commonly, the scale of the resistance measurements opposes the scales of the current and voltage.

AVO meters can be used also for other measurements like inductance and capacitance


ELECTRONIC AVOMETER EA 113
dbm 600 Ω
OFF
mA
Ω
V
60db
-40db
1µA d.c. only
3000
1000
100
10
1
·1
·01
x100
x1K
x10K
x100K
x1M
1000
300
100
30
10
3
1
·3
·1
·03
·01

METER MULTIRANGE No. 15A
G.P.O.
AVO
D.C. VOLTS
A.C. VOLTS
Ω×1
Ω×10
EXT. SHUNT
D.C. AMPS
Z
AVOMETER
12
ADJUST

The moving-coil rectifier instrument

A moving-coil instrument measures only d.c. variables

It can be used with a rectifier to measure ac signals

The average value of the full wave rectified current is **63.662 %** of the maximum current

The meter used to measure a.c. is usually calibrated in r.m.s. Values

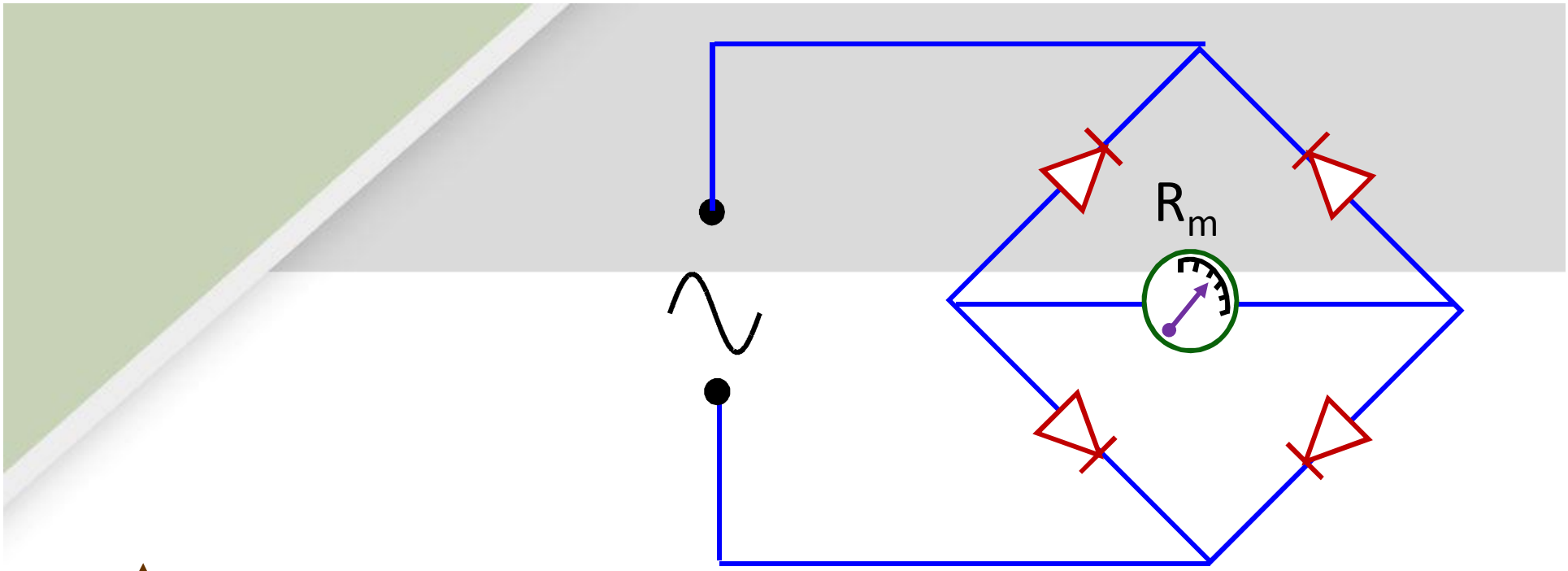
For sin waves, the indication is $(\mathbf{0.707 I_m})/(\mathbf{0.6366\ I_m})$ i.e. $\mathbf{1.110721\ I_{mean}}$

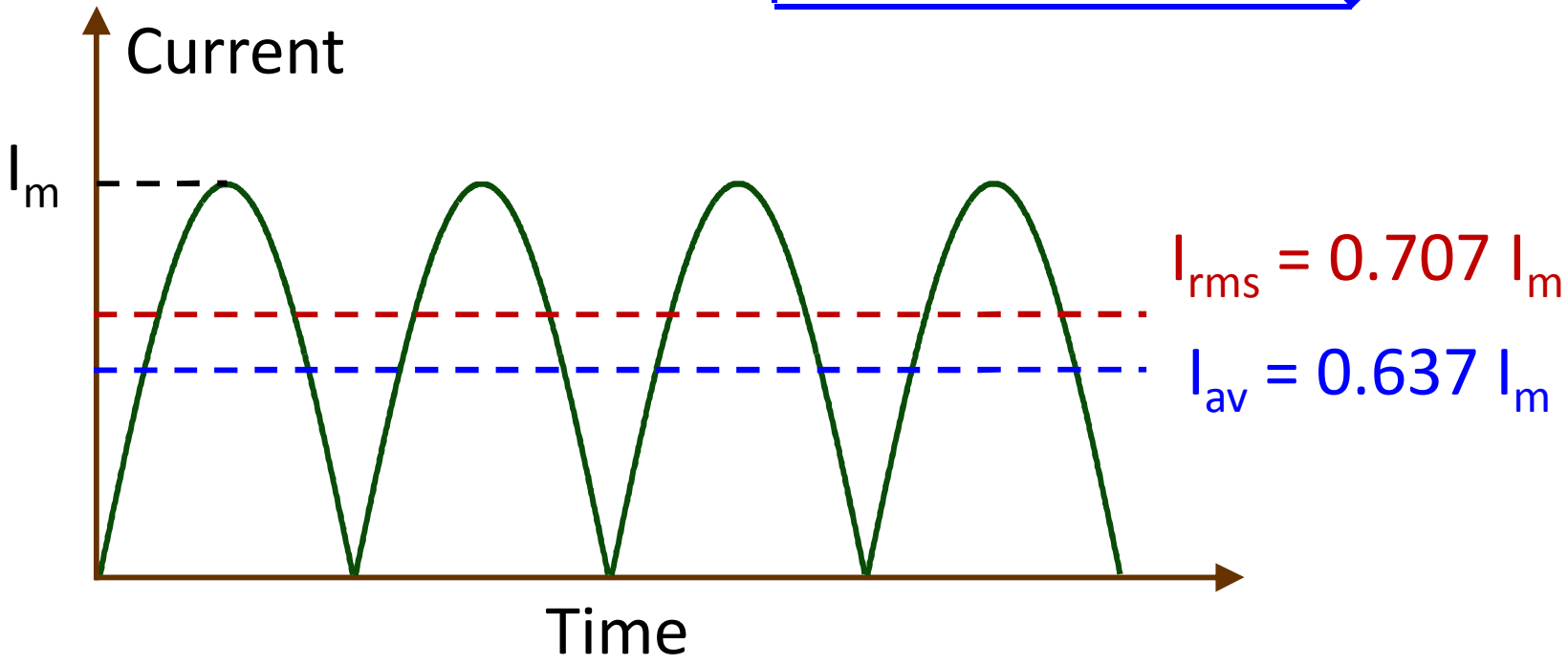
This factor is known as the **form factor**

The rectifier-type moving coil meter is meant to measure r.m.s. values of sinusoidal waveforms

It is calibrated to read 1.11 times the average value

For other waveforms, there is an error


R_m


Current
I_m
Time
$I_{rms} = 0.707\ I_m$
$I_{av} = 0.637\ I_m$

Electrodynamic instruments

The operation is based on the mechanical interaction between 2 different currents passing in 2 coils

A torque is developed proportional to the product of the effective values of the currents

There is a measuring transducer to convert the measured quantity into ac or dc current

It consists of a fixed coil divided into two haves and a movable coil inside the fixed one

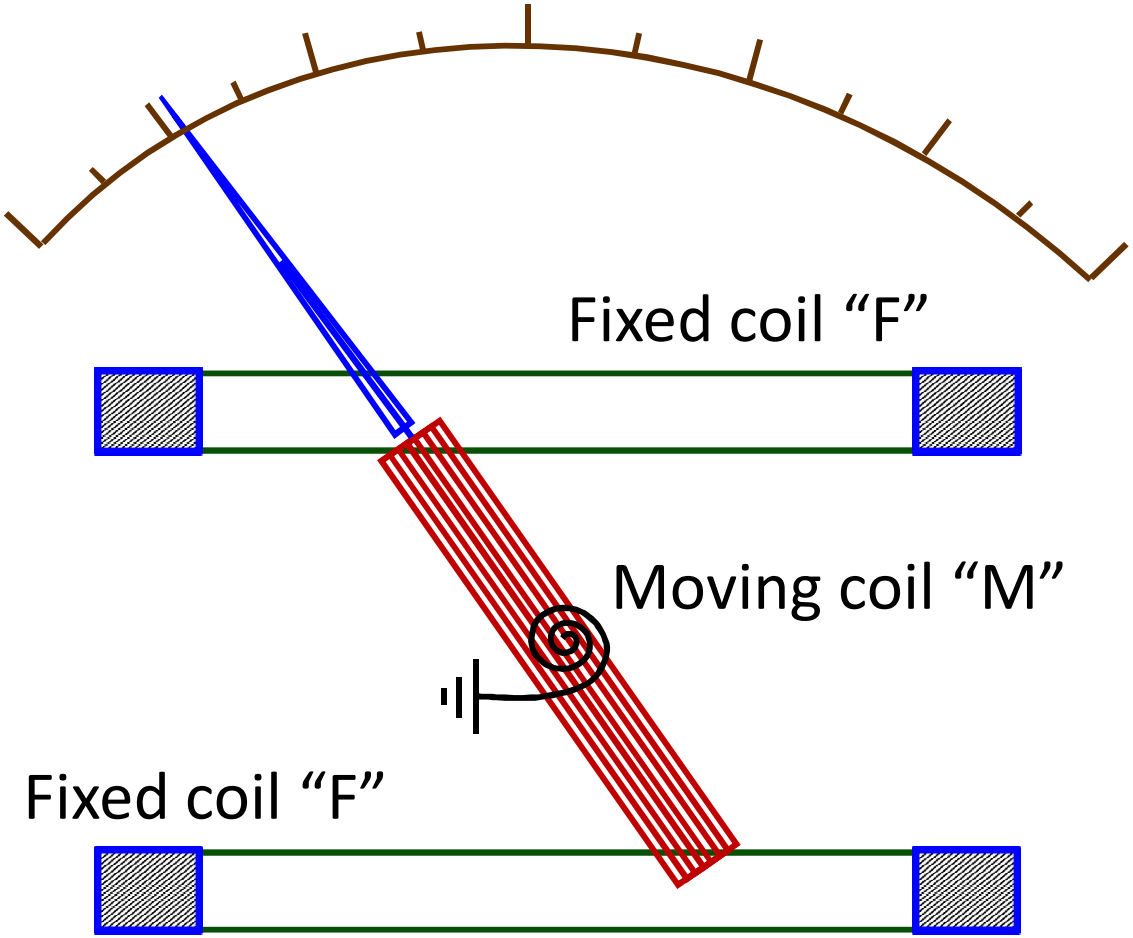
A pointer is fixed to the movable coil and thus, it can move in a calibrated scale

A countertorque is created by a spring

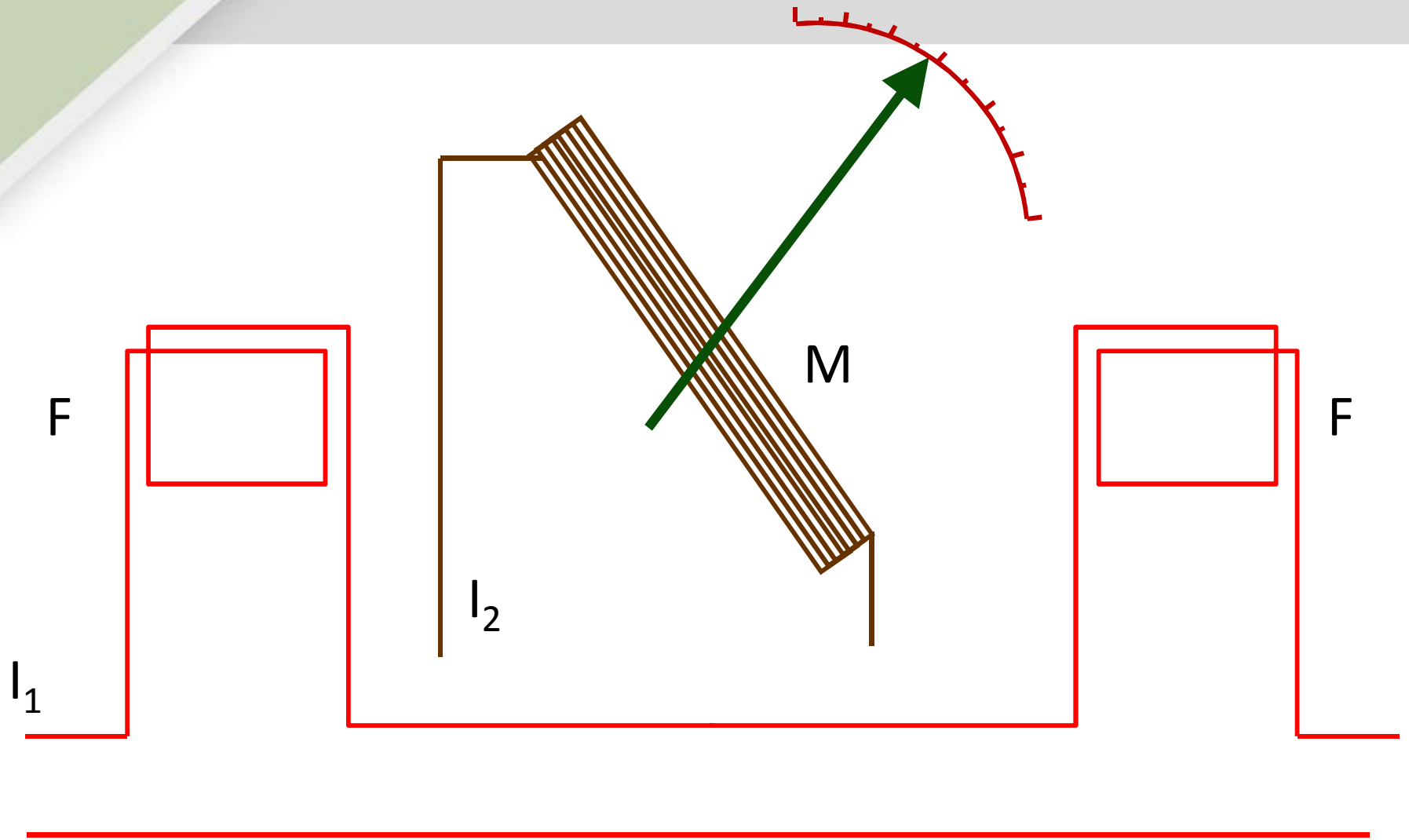
The pointer comes to rest when the two torques are equal

Electrodynamic instruments

Since the operation depends on the electromagnetic action, a shield is required around the components

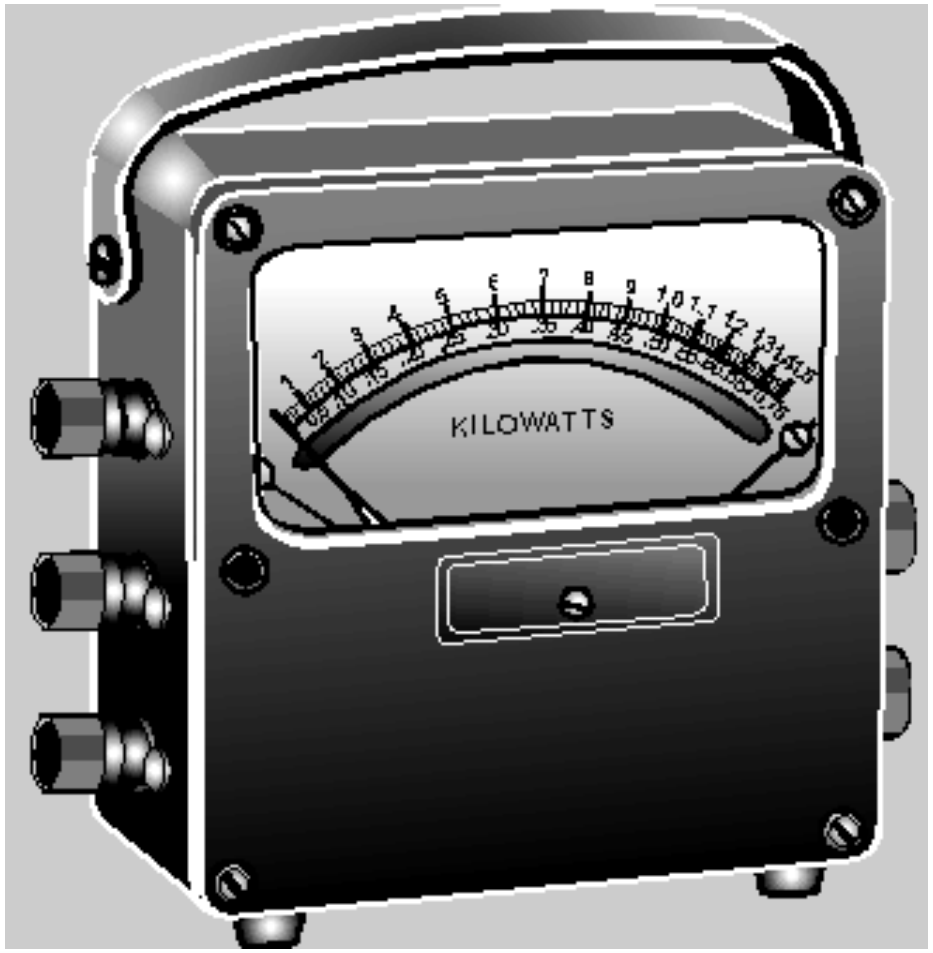


Electrodynamic instruments



Electrodynamic instruments

They are the most accurate instruments to determine effective values of AC and DC currents and voltages

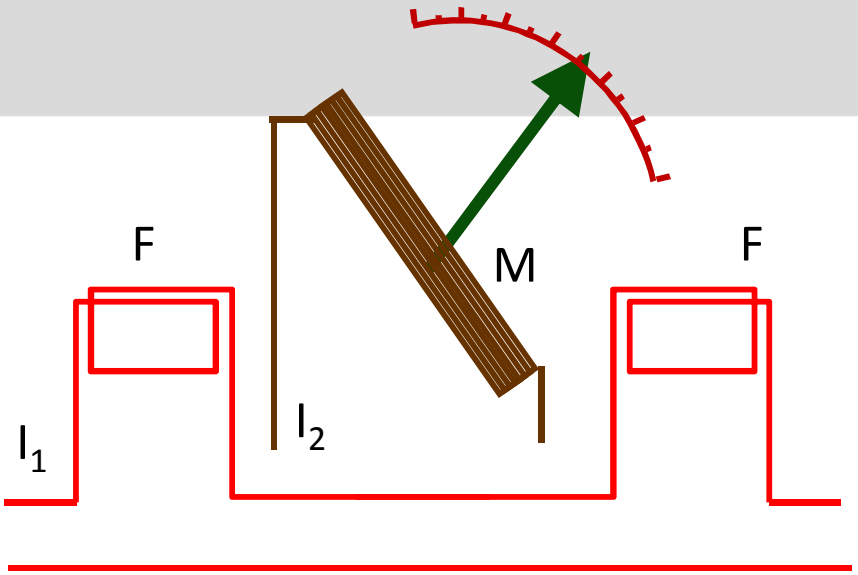


Electrodynamic instruments

Two different currents flow in the two coils

Two fluxes are produced proportional to the two currents

The interaction between the two fluxes caused a torque



The torque is in proportional to the product of the two currents

The moving-coil rotation causes a certain deflection

Electrodynamic instruments

For dc measurements, dc values are measured

The deflecting torque “the average torque” is:

$$T_{av} \propto I_1 I_2$$

$$T_{av} = I_1 I_2 \cos(\phi) \frac{dM}{d\theta}$$

M is the mutual inductance between the two coils

ϕ is the phase shift between the two currents

At steady state, equilibrium is achieved when deflecting torque is equal to controlling torque “the spring torque”

$T_{av} = T_c \rightarrow C \cdot \theta = I_1 I_2 \cos(\phi) \frac{dM}{d\theta} \rightarrow \theta = \frac{I_1 I_2}{C} \cos(\phi) \frac{dM}{d\theta}$

Electrodynamic instruments

The same equation can be applied for ac measurements, where the currents are the rms values

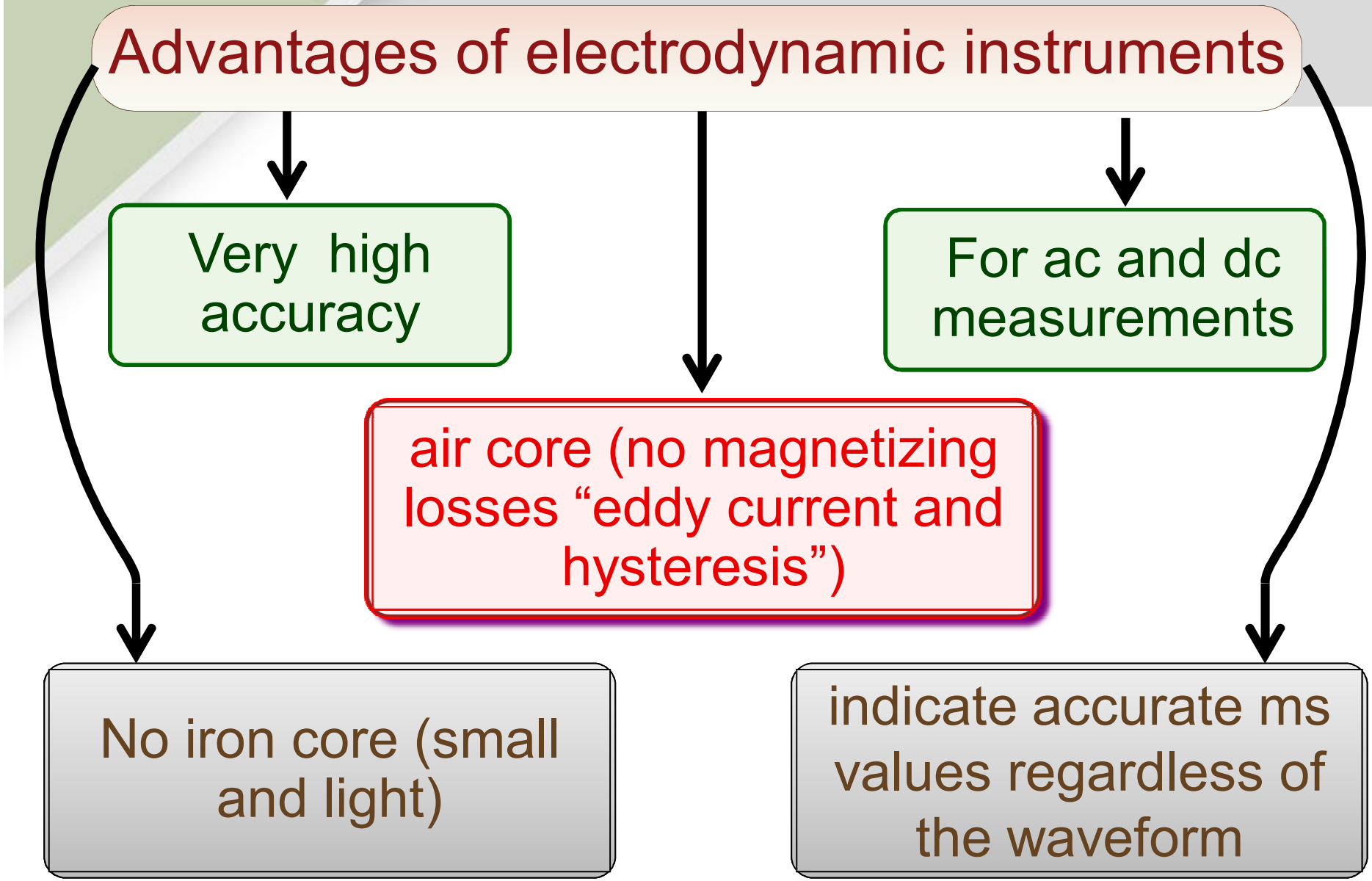
$$T_{av} \propto I_1 I_2$$

$$T_{av} = I_1 I_2 \cos(\phi) \frac{dM}{d\theta}$$

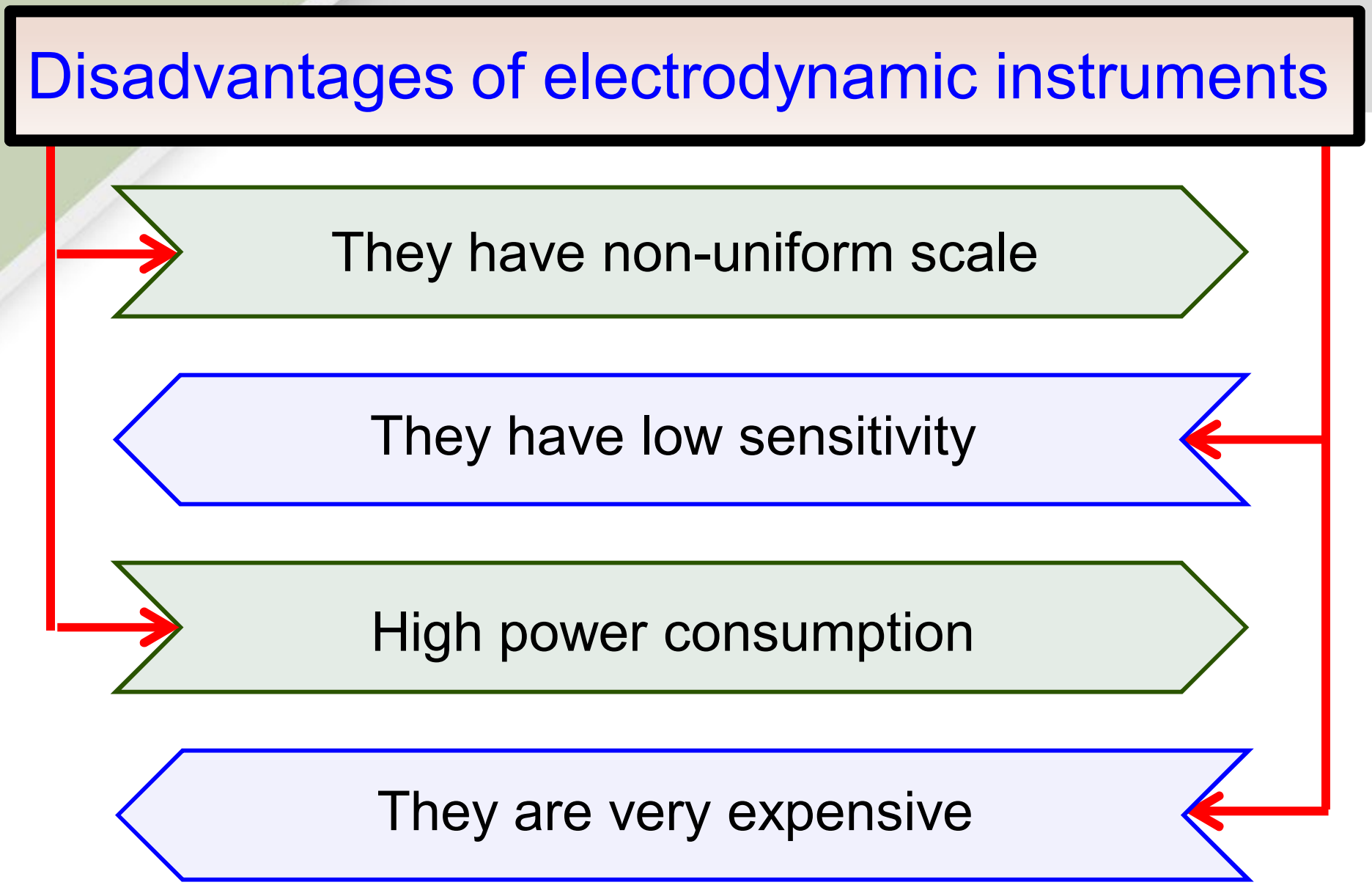
$T_{av} = T_c$ ⟶ $$C \cdot \theta = I_1 I_2 \cos(\phi) \frac{dM}{d\theta}$$

$$\theta = \frac{I_1 I_2}{C} \cos(\phi) \frac{dM}{d\theta}$$

The moving coil instruments



The moving coil instruments



Electrodynamic instruments

When the two coils are connected in series, the deflection is proportional to the square of current

Series connection of the two coils is used for voltage (voltmeters) and current (ammeters) measurements

For power measurements (wattmeters), two different currents have to be applied to the two windings, one of them is the circuit current and the second is proportional to the voltage in the other circuit

The instrument's reading is proportional to the active or reactive power depending on the connection

Electrodynamic mechanisms may also be used as frequency meters, phase meters, and faradmeters

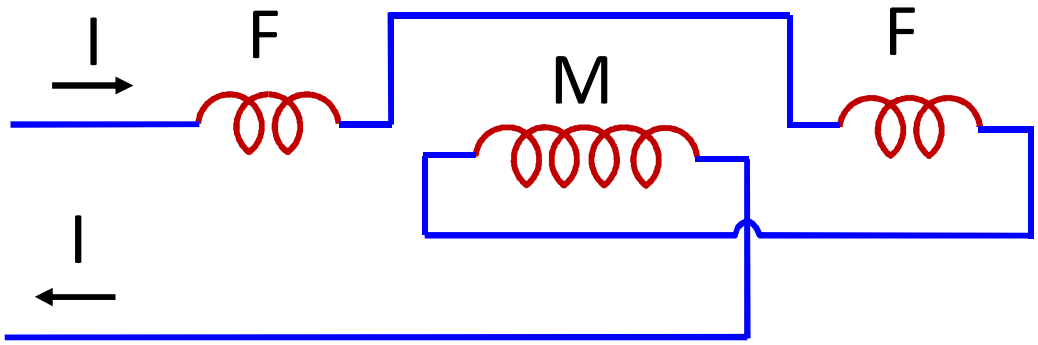
Electrodynamic instruments used as ammeters

With the two coils connected in series, the deflection is in proportional to the square of the current

The movable coil tends to displace itself at the same axis of the fixed coil

This tendency can be resisted by the spring as a restoring torque

This connection is used only for small currents



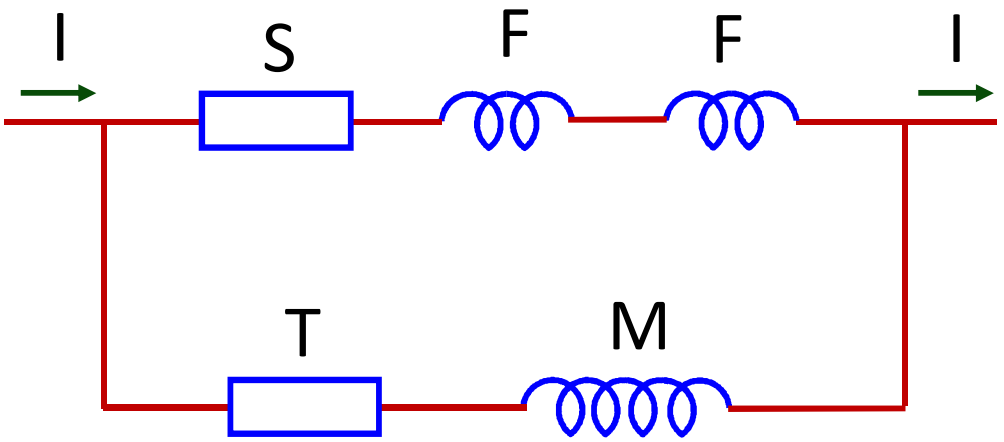
Electrodynamic instruments used as ammeters

For higher currents, a shunt pass has to be formed to extend the measuring range

Both “S” and “T” are non-inductive resistors

The resistor “T” represents a swapping resistor of the moving coil

It is possible to increase the measured currents up to 50A



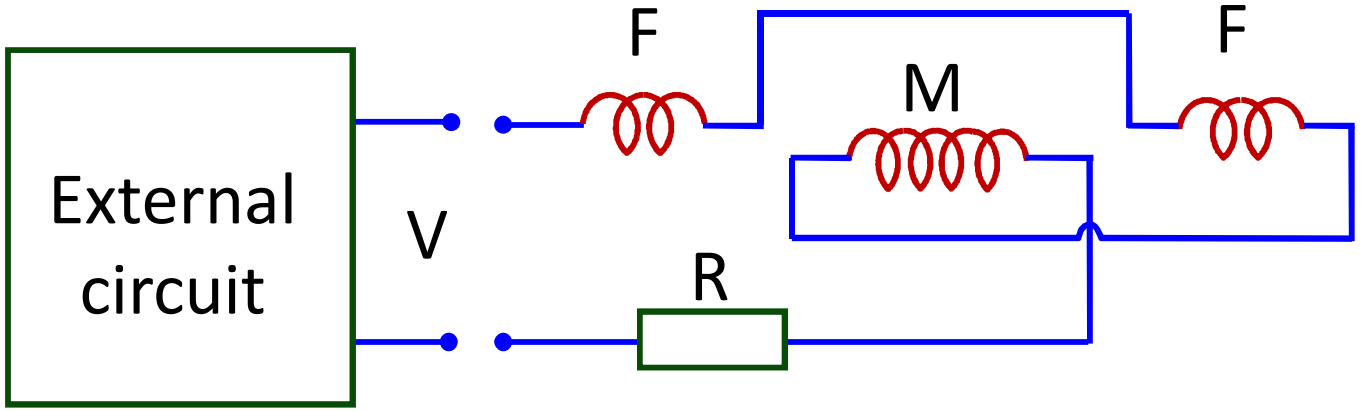
Electrodynamic instruments used as voltmeters

A large resistance is added in series with fixed and moving coils to give suitable instrument resistance

The current flowing in the instrument is proportional to the applied voltage

The angle is an indication of the measured voltage

Since the torque is proportional to the square of current, the scale of the instrument is not linear



Electrodynamic instruments used as Wattmeters

The instantaneous power is the product of the instantaneous values of voltage and current

Signals from current and the voltage are used

One of the coils “current coil” is connected in series with the circuit to enable the current to pass through it

Electrodynamic instruments used as Wattmeters

The second coil “potential coil” is connected in parallel with its current proportional to the voltage

A pointer fixed to the potential coil moves over a scale

The strength of the first field is proportional to the line current and in phase with it

The strength of the second field is proportional to the voltage and in phase with it

Electrodynamic instruments used as Wattmeters

The deflection is proportional to both the current and the voltage on dc circuits

$$T \alpha I_1 I_2 \rightarrow T = k I_1 I_2$$

$$T = k I_1 \frac{V}{R}$$

$$T \alpha P$$

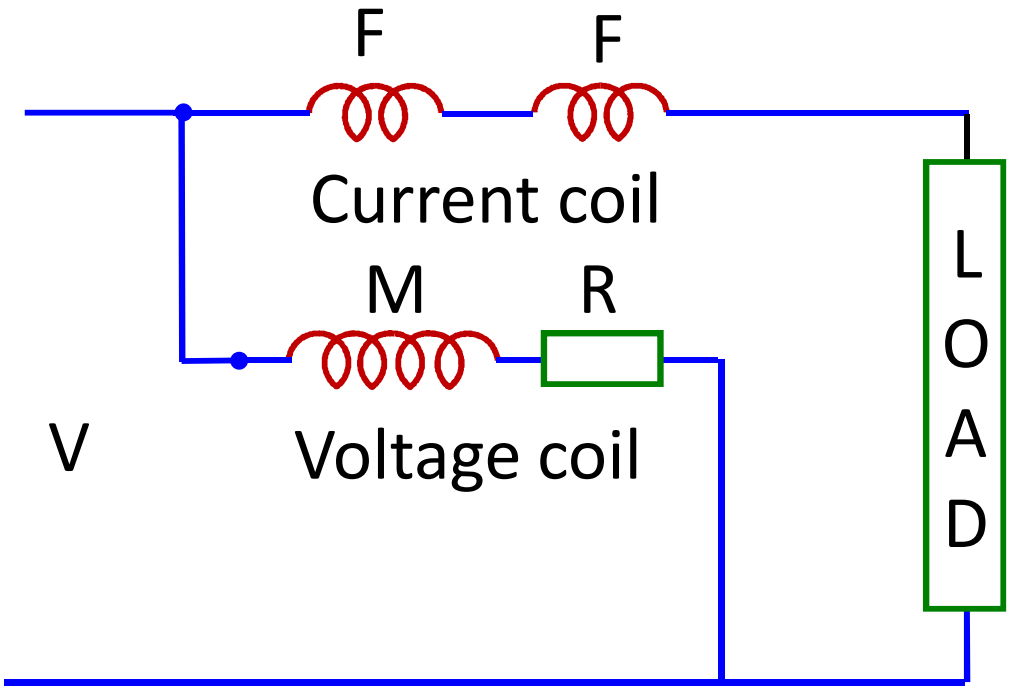
For ac circuits, the pointer does not respond to the instantaneous value but to the mean value of the product of the currents

Electrodynamic instruments used as Wattmeters

The deflection is proportional to the average instantaneous product of voltage and current

The reading will be an indication about the mean value of the instantaneous true power

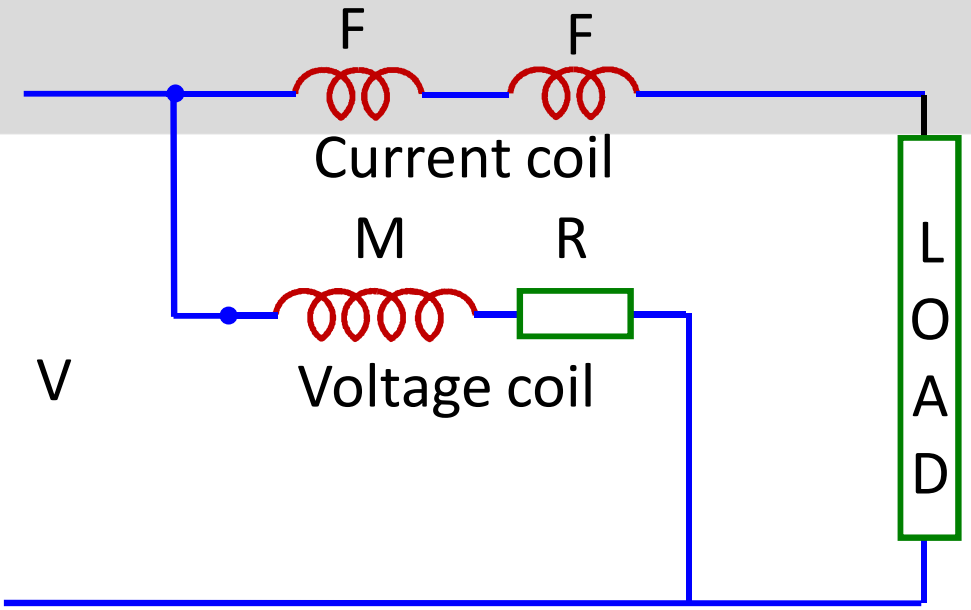
The dynamometer wattmeter can be used to measure both a.c. as well as d.c.



Electrodynamic instruments used as Wattmeters

The resistance "R" is an internal resistance

The fixed coil is drawn as a single coil



$$T \alpha I_1 I_2 \cos(\phi) \rightarrow T = k I_1 I_2 \cos(\phi)$$

$$T = k I_1 \frac{V}{R} \cos(\phi) \quad \rightarrow \quad T \ \alpha \ P$$

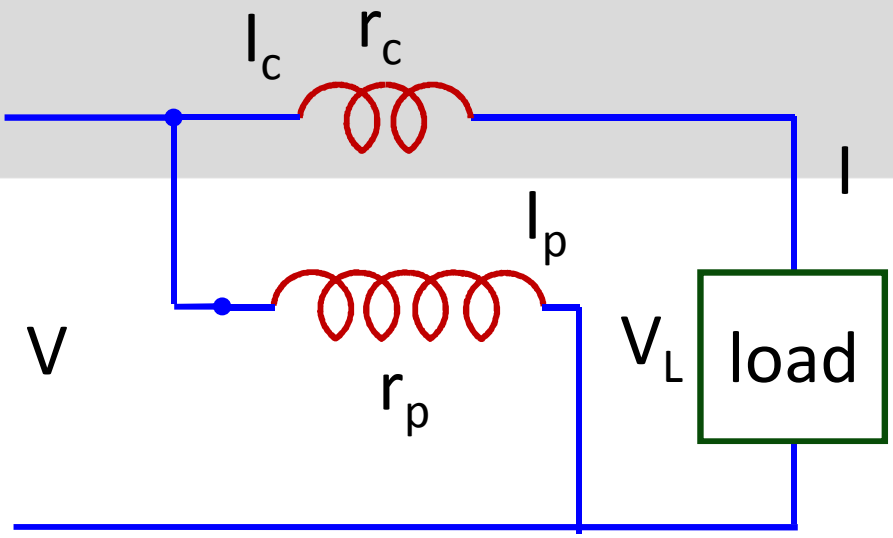
Electrodynamic instruments used as Wattmeters

$I_c = I$

$V = V_p$

$= V_L + r_c I_c = r_p.I_p$

Reading $\propto I_c.I_p$



Reading $\propto I_c.\ V_p \propto I_c.V \propto\ I_c\ .\ (V_L + r_c\ I_c)$

Reading $\propto V_L\ .\ I + r_c I_c^2$

There is an error corresponding to the power loss in the current coil

The current coil must have an almost zero resistance in order for the error to become negligible

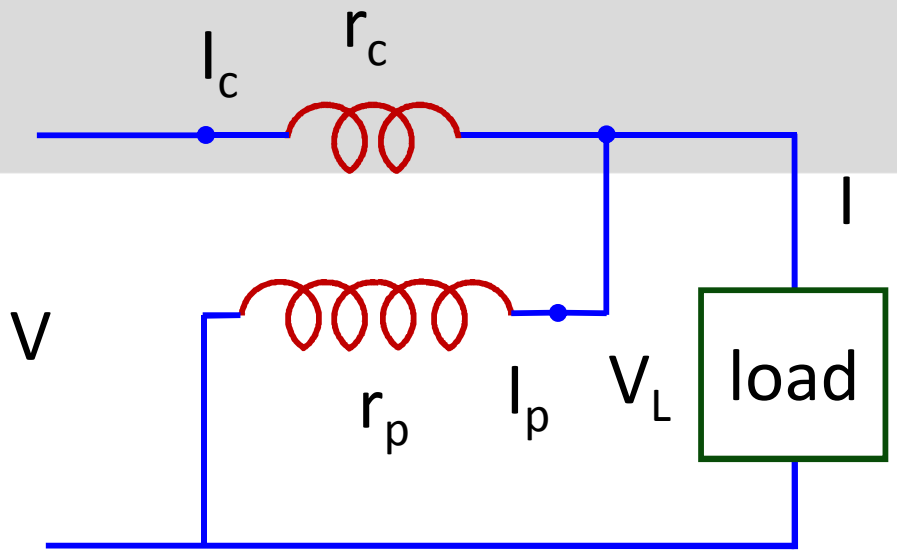
Electrodynamic instruments used as Wattmeters

$V_p = V_L$

$I_c = I + I_p$

$V_p = R_p \,.\, i_p$

Reading $\propto I_c.I_p$



Reading $\propto I_c.\, V_p \propto (I + I_p).V_L$

Reading $\propto I \,.\, V_L + V_p \,.\, I_p \propto I \,.\, V_L + r_p I_p^2$

There is an error corresponding to the power loss in the potential coil

The potential coil must have an almost infinite resistance in order for the error to become negligible

Electrodynamic instruments used as Wattmeters

If ammeters or voltmeters are over loaded, their pointers will be driven off scale

In wattmeters, either or even both the current and potential circuits can be overheated without the pointer approaching the end of the scale

The position of the pointer depends on the power factor, voltage and current

A circuit with a low power factor will give a low reading on the wattmeter, even when both of its circuits are loaded to the maximum safety limit

A wattmeter is rated in volts and amperes

Electrodynamic instruments used as Wattmeters

The wattmeter is often used to measure power in three-phase systems

For a balanced circuit, only wattmeter is used

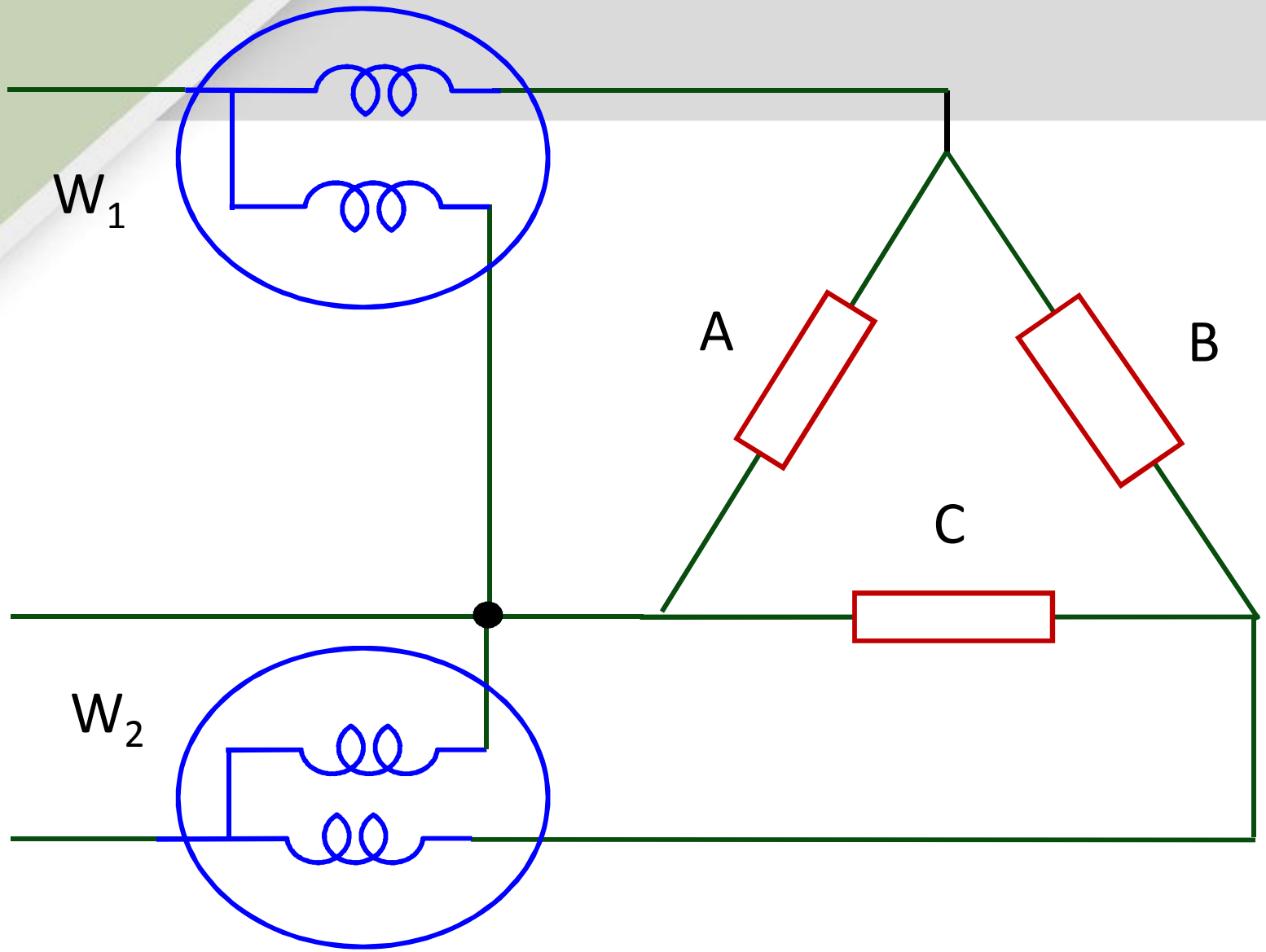
Three wattmeters can be used between the live and the neutral for each phase

Only two wattmeters can be used to measure power in a three-phase system

The sum of powers indicated by two wattmeters is equal to the total power in the system

This dependence is universal and holds for symmetrical or non-symmetrical circuits

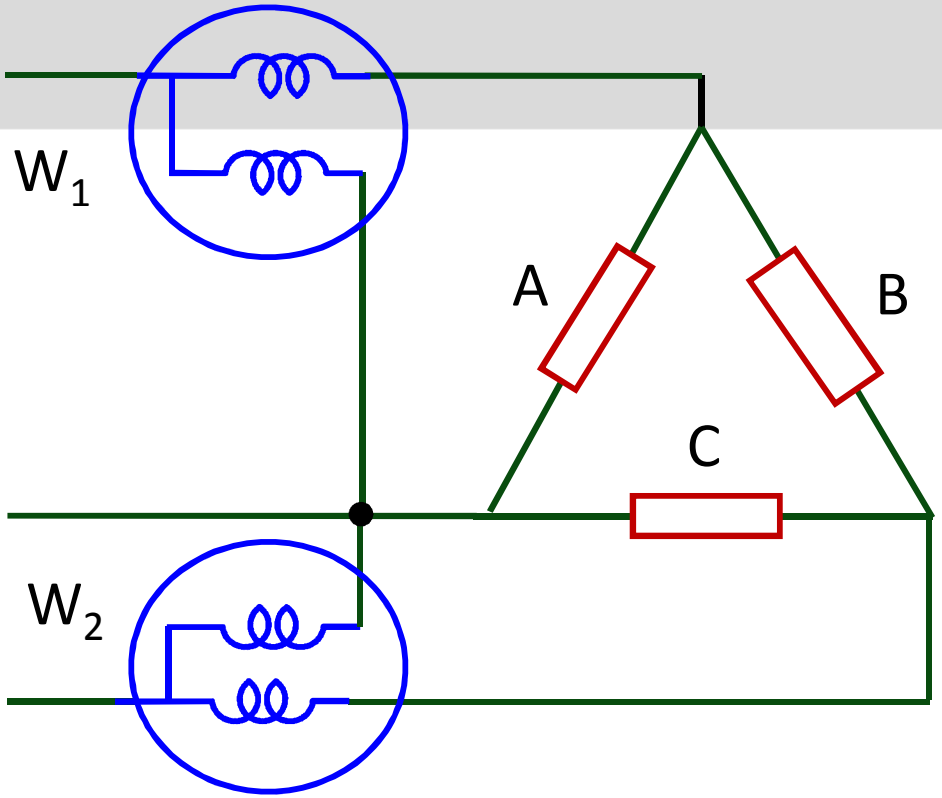
Electrodynamic instruments used as Wattmeters



Electrodynamic instruments used as Wattmeters

The only limit in this method is that the following relation can be applied:

$I_1 + I_2 + I_3 = 0$



The total power of the circuit is:

$P_{total} = P_{W1} + P_{W2}$